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Influence of condensation enhancement effect in nanocapillaries at hydrophilic surface on AFM image contrast

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In order to improve spatial resolution and contrast of atomic force microscopy (AFM) images standard silicon probes could be modified with nanostructures like nanotubes, diamond-type carbon and metal-carbon whiskers and nanowires. Hydrophobicities (hydrophilicities) of the probe and the sample have essential influence on obtained AFM data [1-4]. Phenomenon of the surface features height difference between AFM images (up to contrast inversion) taken with oscillating Si cantilevers corresponding to tapping and noncontact modes was reported in [5-7].

In this work we investigate differences in AFM imaging of nanopores and nanochannels located on the hydrophobic and hydrophilic surfaces obtained using conventional Si probes and Si probes modified with Pt/C wires. In contrast to [5-7] the inversion phenomenon observed in AFM images is associated with effect of enhanced vapor condensation in the nanopores and nanochannels on hydrophilic surfaces. We found that enhanced vapor condensation in nanopores affects on AFM contrast and spatial resolution of hydrophilic surfaces at normal conditions.

For AFM study of surface features on hydrophilic porous samples, two types of probes, namely standard Si cantilever and cantilever modified with single Pt/C nanowire (NW) were used. NWs were produced on the top of silicon cantilevers NSG01 by depositing Pt/C material under focused electron beam in presence of precursor gases in vacuum chamber of scanning electron microscope.

Standard Si probe and Pt/C NW probe approach/retract curves to hydrophilic Au layer deposited on Si wafer were measured in order to obtain data related to the adhesion properties of the probes used. It was shown experimentally that Pt/C NW probe had better adhesion to hydrophilic gold surface and more hydrophilic properties in comparison with standard Si probe.

Hydrophilic surface of different samples (including porous K8 glass, erythrocyte membrane, patterns in PMMA and SU-8 resists) was visualized using both standard Si probe as well as Pt/C NW modified probe in tapping and constant force modes under the same operating conditions. It was shown that use of conventional Si probes provides an inversion of real contrast whereas use of probes modified with hydrophilic Pt/C nanowires provides adequate imaging when mapping objects with dimensions smaller than critical on hydrophilic surface using AFM. The phenomenon of AFM contrast inversion and reasons of the spatial resolution improvement in case of probes modified with nanowires are based on the fact that liquid meniscus shape depends on dimensions of nanochannel [8].

We conclude that handling the AFM data requires to consider the possibility of contrast inversion phenomenon occurrence. The latter may be obtained when using standard Si cantilevers at normal conditions in tapping and contact modes due to the condensation of vapor in the nanochannels and nanopores on hydrophilic surfaces. This phenomenon takes place only when lateral size of surface feature (pore or channel) is less than the critical value of 100 nm which is associated with liquid meniscus shape changing [8]. Unlike standard Si probes the modified probes with Pt/C NW allow to eliminate artefacts in AFM imaging of nanochannels and nanopores on hydrophilic surfaces that leads to improvement in spatial resolution and contrast of AFM images.

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